Search for long-lived heavy particles in $\pi^- U$ interactions at 55-GeV/c incident momentum.

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The effective mass spectrum of $K\pi$ systems produced in the reaction $\pi^- U \rightarrow K^{\mp}\pi^{\pm} + \ldots$ at 55-GeV/c incident momentum was investigated for the purpose of searching for heavy mesons with a lifetime of 10^{-12} to 10^{-10} sec. Narrow resonances were not observed in the 1.3–2.3-GeV mass region of the $K\pi$ systems. Upper limits for the production cross sections of D^0 mesons were estimated.

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An experiment[1] using nuclear emulsions irradiated in a beam of protons with 400-GeV incident momentum determined that the production cross section of charmed stable particles in pN interactions does not exceed 1.5 μb. At the same time, the "beam dump"-type experiments[2] performed in the same energy region possibly indicate that the charmed particles are produced with considerably larger cross sections (>30 μb). As shown in Ref. 3, the results of the above-mentioned experiments do not contradict each other if the lifetime of the charmed particles is either longer than $\sim 10^{-12}$ sec or shorter than $\sim 5\times 10^{-16}$ sec. We attempted to record the charmed D^0 mesons with a lifetime $\geqslant 10^{-12}$ sec in the reaction

$$\pi^- + U \rightarrow D^0 + X, \quad D^0 \rightarrow K^{\pm}\pi^{\mp}.$$

The experiment was performed using the "Sigma" spectrometer (Fig. 1). The beam of π^- mesons with 55-GeV/c momentum was focused on a 4-mm-thick uranium target. The momenta of the secondary particles emitted from the target were measured by using a spectrometer magnet M and wire spark chambers SC. The field in the magnet was chosen in such a way that the trajectories of the π^- and K mesons from the $D^0 \rightarrow K\pi$ decay would be parallel behind the magnet. The particles were identified by using an eight-channel threshold Cerenkov counter C.[4] The Cerenkov counter separated the π mesons and the heavier particles in the momentum range of 6 to 21 GeV/c. The scintillation hodoscopes H4 and H5 (64 counters in all) were used to form the trigger. To produce a trigger signal the different sections of the Cerenkov counter C had to pass at least two charged particles, one of which had to be registered by the Cerenkov counter.

During the experiment 2.6×10^{10} π^- mesons passed through the target and about 2×10^6 events were recorded on the magnetic tapes. As a result of evaluating the data, events satisfying the following criteria were selected:

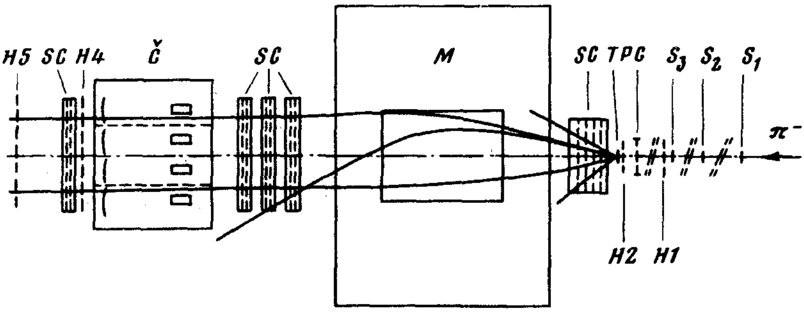

FIG. 1. Schematic of the experimental setup: $S_1 - S_3$, beam scintillation counters; $H\,1$ and $H\,2$, beam scintillation hodoscopes; *PC*, beam proportional chamber; *T*, uranium target; *SC*, wire spark chambers; *M*, spectrometer magnet; *C*, eight-channel threshold Cerenkov counter; $H\,4$ and $H\,5$, scintillation hodoscopes.

1) At least one positive and one negative secondary particle were recorded by the spark chambers and scintillation hodoscopes. 2) The particle momenta were in the range of 6 to 21 GeV/c. 3) The particle trajectories were within the limits of the angular acceptance of the Cerenkov counter ($\pm$ 50 mrad). 4) One of the particles was recorded by the Cerenkov counter (this particle was assumed to be the pion) and the other was not (it was assumed to be the kaon).

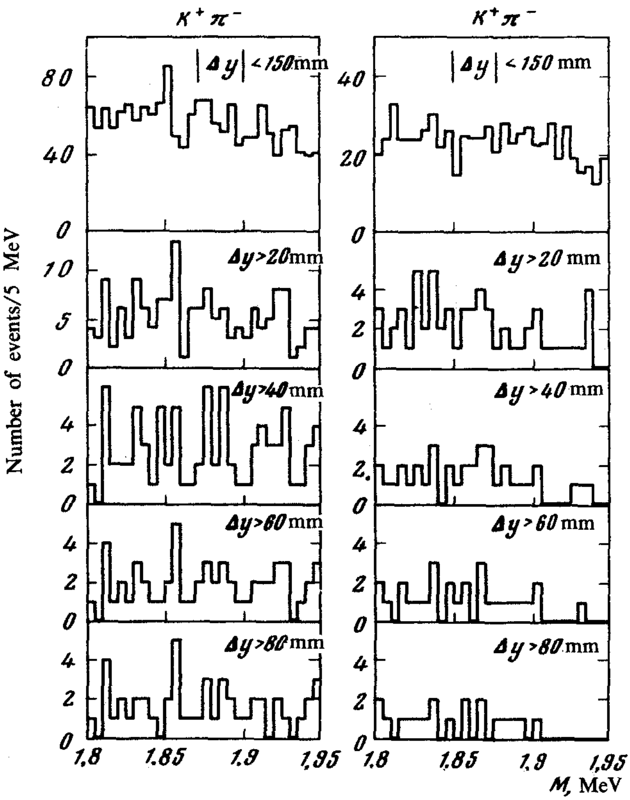

FIG. 2. Spectra of effective masses of $K\pi$ systems for different distances $\Delta\, y$ between the target's center and the reconstructed $K\pi$ vertex.

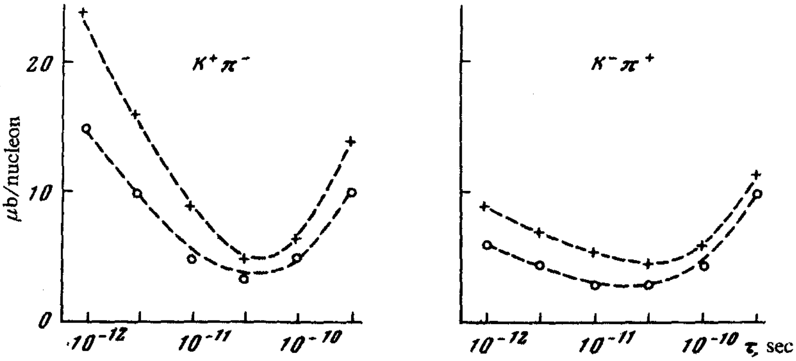

FIG. 3. Dependence of the estimate of the upper limit of the production cross section of D^0 mesons on the lifetime τ (○, diffractive mechanism of production of the $D^0\bar{D}^0$ pair; +, the $D^0\bar{D}^0$ system is produced similarly to the J/ψ particle).

As a result of such selection 7732 $\pi^- K^+$ and 3139 $\pi^+ K^-$ events remained. For each of these events the $K\pi$ vertex was reconstructed in the chambers in front of the magnet. The error in determining the vertex was $\sigma = 8$ mm in the 1.8 to 1.9-GeV mass region of the $K\pi$ system. By choosing events where the difference between the coordinate of the vertex and that of the target's center Δy is larger than a certain value, we can decrease the background from the "direct" $K\pi$ events and consequently improve the signal-to-noise ratio for the D^0 mesons, if the lifetime of this particle is sufficiently long. The spectra of the effective masses of the $K\pi$ systems in the 1.8 to 1.95-GeV range for different values of Δy are shown in Fig. 2. The mass resolution of the spectrometer, which is $\sigma \approx 10$ MeV, was determined from the data of a special experiment in which the $K_s^0 \rightarrow \pi^+\pi^-$ decays were recorded. It can be seen in Fig. 2 that the mass region of the D^0 meson has no statistically significant signal. There were also no narrow resonances observed in the wider mass interval of 1.3 to 2.3 GeV.

The spectra of the effective masses shown in Fig. 2 were fitted by a relation of the form

$$N(M) = \frac{N_0}{\sqrt{2\pi}\sigma} \exp\left[-\frac{(M - M_0)^2}{2\sigma^2}\right] + P(M),$$

where $M_0 = 1.863$ GeV is the mass of the D^0 meson, $\sigma = 10$ MeV, and $P(M)$ is a polynomial that describes the nonresonance background. The upper limit of the number N_0 of events at the peak corresponding to the 95% confidence level was estimated for each spectrum. To determine the upper limit of the production cross section of D^0 mesons σ_m, we calculated the detection efficiency for D^0 mesons of different lifetimes τ. In these calculations we used two dynamical models of the D^0-meson production. In the first model it was assumed that the DD^- system has a diffractive mechanism of production and in the second model it was assumed that the distribution of the DD^- system according to the Feynman variable x and $p_\perp^2$ is the same as that for the J/ψ particles.[5] There is an optimum Δy for each value of τ for which the estimate of σ_m is minimum. The obtained $\sigma_m(\tau)$ dependences are shown in Fig. 3. In calculating σ_m we assumed that the cross section for production of the D^0 meson in the nucleus is proportional to its atomic weight. It follows from Fig. 3 that the cross section for production of D^0 mesons with a lifetime of $\sim 10^{-11}$ sec in the $\pi^- U$ interactions at 55 GeV/c does not exceed 5 μb/nucleon.

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